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(58) Field of search
Selected US specifications from IPC sub-class G01S

(54) Measuring angular deviation

(57) The angular deviation of an object is measured using an object-related target mark constructed as an optically structured screen, and using digital photoelectric evaluation of the target image. The information values obtained are compared with a reference corresponding to the target mark. The target 1, provided with a clearly defined centre 9, is imaged onto a detection plane 10 of a receiving apparatus 3. The resulting target image is scanned with the aid of a subdivided position-sensitive, photoelectric detector 5 provided with detection regions 11 within the detection plane 10. The resulting values undergo correlation comparison 6 with values derived from the stored reference and from this is calculated the deviation of the centre of the target from the optical axis. It has proved particularly advantageous to have a mark comprising constructed as a radial pattern with circular sectors of alternately light and dark regions (7, 8, fig 4), which coverage in the common centre (9, fig 4) and in which adjacent regions subtend a random angle.

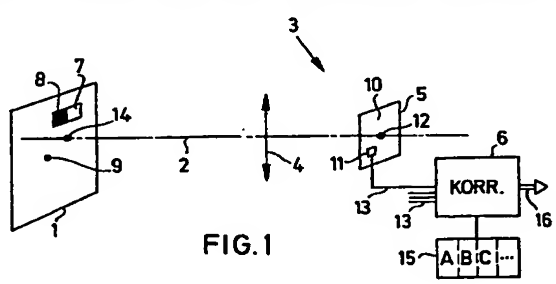

FIG.1

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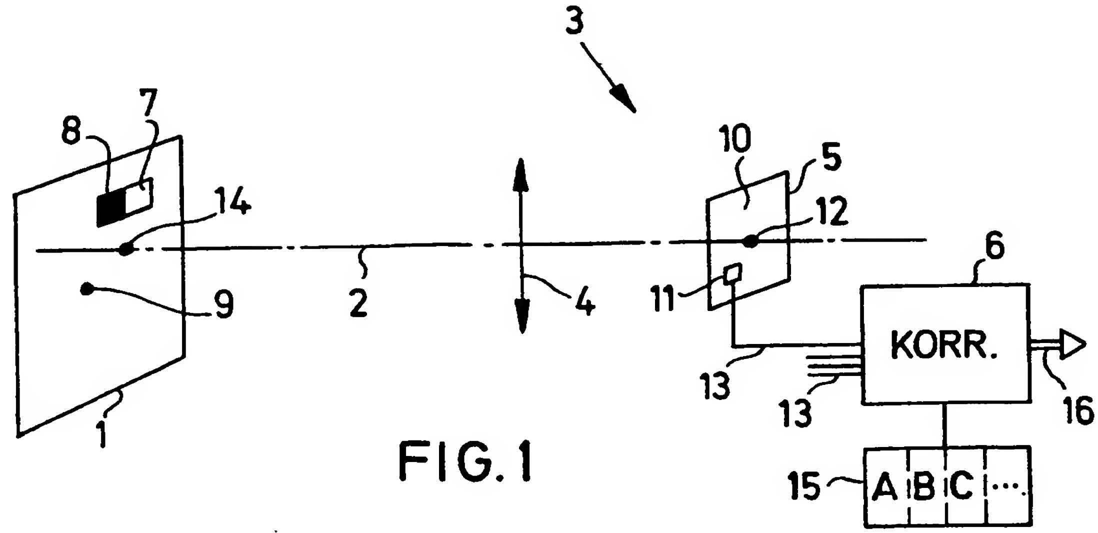

FIG. 1

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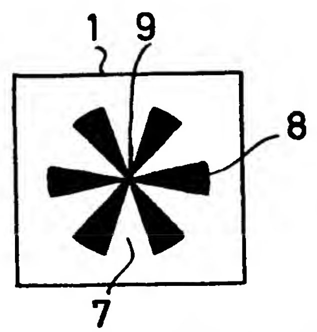

FIG. 2

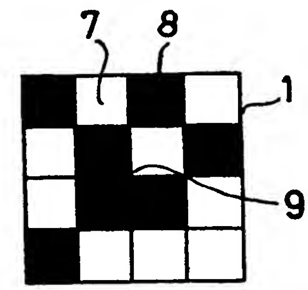

FIG. 3

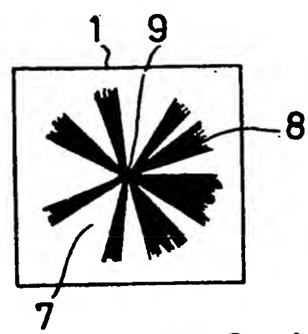

FIG. 4

SPECIFICATION

Measurement of angular deviation

Field of Invention

The invention relates to measurement of angular deviation and concerns a method and an apparatus for measuring the angular deviation of an object with the aid of target marks or targets constructed as optically structured screens.

Background to the Invention

For the measurement of angular deviations, such as eg occur in geodesic instruments such as theodolites, levels and the like, hitherto essentially purely optical methods have been used. With the introduction of electronic means for range finding with such equipment, there is an increasing discrepency in the accuracy of the measured results as obtained on the one hand via the electronic means and on the other via purely optical means during angular measurements.

Swiss patent 638 057 discloses an apparatus for determining the direction of a target by determining the position of an objectified or projected image of the target on a transmitted light screen. The target is optically structured as a reflected light screen with rotationally symmetrical, substantially radially directed, alternating light and dark divisions. The receiving apparatus essentially comprises a lens or objective directed on to the target, a transmitted light screen and behind the latter radiation detectors, together with an evaluation circuit. The transmitted light screen has the same optical structure as the reflected light screen, is rotatable about its centre of symmetry and driven by a motor. The centre of the transmitted light screen and the centre of the radiation detectors are aligned with the optical axis of the lens. For determining the angular deviation of the target with respect to the optical axis of the lens a modulation of the signals emitted by the radiation detectors is brought about by rotating the transmitted light screen. This modulation is evaluated by the evaluation circuit, which calculates the deviation and makes available corresponding values. These values are stored, displayed or supplied in some other way.

A disadvantage of this apparatus is the considerable expenditure involved on mechanical and electronic equipment, including the drive for the transmitted light screen whilst avoiding vibrations, and the regulation of the rotational speed within a range which is admissible for the calculation. A further disadvantage is that the screen can only be changed with difficulty, so that it is not possible when used under practical conditions to process several targets located in the field of vision of the apparatus without manual access to the latter. It is therefore impossible to use the apparatus for identifying several different marked targets.

The present invention aims to provide an improved method and apparatus of the aforementioned type so as to enable the high speed measurement of the angular deviation, whilst eliminating as far as possible reading errors, the integration of the method and/or apparatus into electronic range finders being desirable. The invention also aims to provide a method and apparatus with which it is possible to carry out very acurate measurements on inaccessible or hard of access objects, and with which it is possible to identify several differently marked targets.

Summary of the Invention

According to one aspect of the invention, there is provided a method for measuring the angular position of an object with the aid of object-related targets or target marks constructed as optically structured screens by the digital photoelectric evaluation of an image of the target mark and the comparison of the thus obtained information values with a reference mark corresponding to the target mark, wherein the target provided with a clearly defined centre is imaged within a receiving apparatus as a target image directly on the detection plane, serving as an image plane, of a position-sensitive photoelectric detector subdivided into detection regions, wherein the thus obtained values are compared with the reference mark or with stored values which characterise the reference mark and wherein from the comparison result the deviation of the centre of the target from the optical axis of the receiving apparatus is calculated.

In a further aspect the invention provides apparatus for performing the method of the invention, wherein a planar radiation detector provided with detection regions is arranged in fixed manner in the receiving apparatus with its optical axis, the centre thereof located on said optical axis, wherein the detection regions are connected via connecting lines to the input of a comparison computer and wherein to the latter is connected a memory means in which are stored the reference marks or characteristic values of such reference marks corresponding to the target to be surveyed.

An advantage of the invention is that need not require the use of mechanically moving parts, eg rotary parts. Further, the photoelectric detector may comprise a diode array, which is a particularly simple, inexpensive radiation detector. As computers already exist in such apparatus, the additional computer requirement for the invention leads to no significant extra expenditure with respect to the present apparatus.

In embodiments using a scale-invariant construction as the target, it is also possible to detect targets which are oblique to the optical axis on difficulty accessable or inaccessable target objects.

It is also possible to store several reference marks in the apparatus, which makes it possible to process several targets located in the field of vision thereof, without manual intervention in the apparatus being required for changing reference marks. This leads to the possibility of a particularly simple and reliable target identification in the case of multiple measurements.

Brief description of the drawings

The invention is described in greater detail hereinafter, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a diagrammatic representation of an apparatus according to the invention;

Figure 2 illustrates a first construction of a target with a centrosymmetrical pattern;

Figure 3 illustrates a second construction of a target with a mosaic-like surface pattern; and

Figure 4 illustrates a third construction of a target mark with a pseudostochastic radial pattern.

Detailed description of the drawings

The arrangement illustrated in Figure 1 comprises a target or target mark 1, which is linked or associated with the object to be surveyed and which is located in the optical axis 2 of a receiving apparatus 3. Apparatus 3 comprises a lens 4 aligned on the optical axis 2, a position-sensitive radiation detector 5 and computer means 6 to which can be connected a store or memory means 15.

The target 1 is constructed as a reflected light screen and is optically structured by divisions into light and dark areas 7, 8, respectively. However, the target can also be constructed as a transmitted light screen without there being any need to modify the essential features of the method or apparatus. A predetermined point of the target 1, which is surrounded by light and dark areas 7,8 is defined as centre 9. Target 1 is intersected in the sighted point 14 by the optical axis 2 of the receiving apparatus 3. Suitable arrangements of patterns of light and dark areas, eg in the form of a radial or mosaic pattern, will be discussed below.

An image of the target to be processed is stored in the store 15 as a reference mark for comparison purposes. Storage can take place by means of the actual optical image of the reference mark or by means of suitably processed characteristic values of said mark. It is also possible to store images or characteristic values of reference marks corresponding to several different targets.

Radiation detector 5 is eg of the so-called sector type, being subdivided into several radiation-sensitive detection regions 11 which constitute the radiation-sensitive surface. The detection regions 11 are arranged regularly in a detection plane 10, eg in a circle or in matrix-like manner.

In the preferred embodiment the radiation-sensitive detection regions 11 of such a radiation detector 5 are constructed as a matrix of diodes on a semiconductor substrate, being known as a diode array. Each of these radiation-sensitive diodes is led to the outside via electrode terminals. A base electrode is common to all the detection regions. In the preferred embodiment a particular point of the radiation-sensitive surface of the radiation detector 5 is defined as the centre 12, which is surrounded by the detection regions 11.

When selecting the dimensions of the lens 4, the dimensions of the target 1 and the radiation detector 5 must be taken into account in such a way that an image objectified or projected by lens 4 on to detection plane 10 adequately covers the radiation-sensitive surface of radiation detector 5. If the centre 9 of the target is alongside the optical axis 2, it is necessary for the image of target 1 in detection plane 10 to cover the radiation-sensitive surface of radiation detector 5 by a minimum percentage, eg up to 20%, so as to ensure clarity in target detection and consequently ensure an adequate precision of the position determination.

Detection regions 11 are connected by lines 13 to computer means 6 which, from the thus supplied signals, calculates the deviation of the projected centre 9 of target 1 in the detection plane 10 from the centre 12 of the radiation-sensitive surface of radiation detector 5. It is possible to derive therefrom the deviation of the centre 9 of target 1 from the sighted point 14 at which the optical axis 2 intersects target 1. The computer compares the optical structure of target 1 or its projected image in the detection plane 10 of radiation detector 5 with a pattern corresponding to the optical structure of the target and stored in computer 6 or its memory 15. The optical structure of the target image is supplied to the computer by the signals of the plurality of detection regions 11 of radiation detector 5. At output 16 of computer 6, the signals are made available for display or for storage or further processing. A correlation comparison can in particular be provided as a comparison algorithm for computer 6.

The comparison performed by computer 6 for determining the angular deviation of the target or the object linked therewith can take place in different ways. For example, the autocorrelation function of the stored pattern stored in store 15 may be compared with the correlation function between the pattern and the target. The deviation is then calculated from the comparison result. Such correlation calculations are fundamentally known and do not have to be described in detail here. The calculation can be performed by corresponding programing of computer 6.

As a further possibility, the computer can form a cross-correlation between the stored reference pattern image and the target image. The sought angular deviation is then associated with the maximum value obtained, ie the empirically determined maximum of the cross-correlation function. This calculation can also take place through corresponding programming of computer 6.

Referring to Figure 2, the illustrated example of target 1 comprises a centrosymmetrical radial pattern of light and dark regions. The alternately light and dark regions 7 and 8 are arranged in the form of radial sectors around centre 9 and are angularly displaced with respect to one another by a clearly defined centre angle. The advantage of such an arrangement is in its scale-invariance during the correlation calculation in computer 6. This means that the representation of the target on radiation detector 5 can take place with a constant scale throughout the measuring process.

In place of the previously described overall comparison by computer 6 in the case of such centrosymmetrical targets, according to a variant the centre of a target can be determined by detecting the edges or boundaries between the regions of different intensity. For example, along the radially or otherwise regularly oriented edges with respect to the centre, the edges are detected from a measurement of correspondingly arranged or selected picture or image elements. This can take place by an individual comparison of selected image points. Corresponding interpolation methods or the algorithms necessary for the calculation are known per se and need not be described in detail.

According to another embodiment shown in Figure 3, the target 1 is constructed as a mosaic pattern of light and dark areas. In this case the distribution of the light and dark mosaic elements 7 or 8 around the centre 9 of target 1 is stochastic or at least pseudos-

tochastic. This leads to particularly good reliability and accuracy during the cross-correlation comparison. Diverging from the representation shown, the mosaic elements can also have a different size. The evaluation of the target image in the computer takes place in the same way as described hereinbefore in connection with the target of Figure 2. The target of Figure 3 is particularly advantageous in conditions in which range information is available, because the selected pseudostochastic pattern is not scale-invariant.

According to a further embodiment shown in Figure 4, the target 1 is constructed as a radial pattern with a stochastic or pseudostochastic radial division The aternately light and dark areas 7, 8 are arranged around centre 9 as radial sectors, whose centre angle has stochastically distributed, non-regular values. The radial pattern according to Figure 4 is scale-invariant, like that of Figure 2, so that when evaluating the measurement there is no need for any correction corresponding to the distance between the target and the receiving apparatus.

Compared with the embodiments of Figures 2 and 3, the construction of the target according to Figure 4 offers a further, important advantage. If the plane of target 1 is oblique instead of perpendicular to the optical axis, through a simple, per se known homothetic transformation in the computer, the target is mathematically straightened. Through such a scale transformation in an axis passing through the centre of the target image, in a simple, but very effective manner, a precise angular measurement is still possible if the target is oblique or is located on poorly accessible of inaccessible objects.

According to an already mentioned advantageous construction of the present apparatus several reference patterns, A, B, C etc are stored in computer 6 or memory 15 associated therewith and correspond to several alternatively usable target patterns. Through simple programmed switching in computer 6 from one reference pattern to another it is possible to process several targets located in the field of vision of receiving apparatus 3, the apparatus being in a position to clearly differentiate, ie identify different targets. The direction determination oriented on one of these targets is not disturbed by the other targets also in the field of vision of the receiving apparatus during the comparison with the reference mark sought from memory 15. The measurements obtained are clear and unambiguous through the association between reference and target mark performed in the computer.

Non-scale-invariant target marks, eg sighting targets subdivided in mosaic-like manner and much as in the embodiment shown in Figure 3, permit the provision of a fine code superimposed on the basic pattern by an appropriate choice of the pattern distribution. This fine code can be additionally evaluated by the receiving apparatus and in the present case it can contain additional information concerning its relative geometrical position within the target. The fine code can eg be provided in the form of a bar code on the dark areas 8 according to Figure 3, so that these areas are also screen-patterned. On the other hand this improves the clarity for detecting the target for short distances, and on the other hand for longer distances facilitates the detection by differing shades of grey caused by the fine code.

CLAIMS

1. A method for measuring the angular position of an object with the aid of object-related targets or target marks constructed as optically structured screens by the digital photoelectric evaluation of an image of the target mark and the comparison of the thus obtained information values with a reference mark corresponding to the target mark, wherein the target provided with a clearly defined centre is imaged within a receiving apparatus as a target image directly on the detection plane, serving as an image plane, of a position-sensitive photoelectric detector subdivided into detection regions, wherein the thus obtained values are compared with the reference mark or with stored values which characterise the reference mark, and wherein from the comparison result the deviation of the centre of the target from the optical axis of the receiving apparatus is calculated.

2. A method according to claim 1, wherein a cross-correlation comparison is performed, the maximum of the cross-correlation being determined and the determined value being used to determine the sought angular deviation of the target centre from the optical axis of the receiving apparatus.

3. A method according to claim 1 or 2, wherein in the case of several target images located in the field of vision of the receiving apparatus, a correlation comparison is performed with a stored supply of reference images or their characteristic values.

4. A method according to claim 1, 2 or 3, using centrosymmetrical targets, wherein characteristic target image contents oriented mathematically on the target centre are scanned for image points by the detector, and wherein the scan result undergoes image processing with the aid of a previously defined algorithm and is based on the comparison operations with previously stored reference values.

5. Apparatus for performing the method according to claim 1, comprising a planar radiation detector, provided with detection regions, arranged in fixed manner in the receiving apparatus, the centre of the detector being located on the optical axis of the receiving apparatus, the detection regions being connected to the input of computer means, with the computer means being connected to memory means in which are stored reference marks or characteristic values of such reference marks corresponding to the target to be surveyed.

6. Apparatus according to claim 5, wherein the target mark is constructed as a radial pattern with circular sectors of alternating light and dark regions converging in a common centre.

7. Apparatus according to claim 6, wherein the centre angles of adjacent regions have stochastically selected differing values.

8. Apparatus according to claim 6, wherein the centre angles of adjacent regions have pseudostochastically selected differing values.

9. Apparatus according to claim 5, wherein the target is constructed as s mosaic pattern with light and dark regions, which are arranged around a clearly defined centre.

10. Apparatus according to claim 9, wherein the mosaic pattern is constructed round the centre in accordance with a stochastic distribution of the light and dark regions.

11. Apparatus according to claim 9, wherein the mosaic pattern is constructed according to a pseudostochastic distribution of the light and dark regions around the centre.

12. Apparatus according to claim 9, 10 or 11, wherein at least portions of the regions on the target are constructed corresponding to a fine code containing additional information.

13. Apparatus according to claim 12, wherein a fine code related to the relative geometrical position within the target is provided on selected regions of the latter as additional information.

14. Apparatus according to claim 13, wherein the fine code is placed on the dark regions of the target in such a way that said dark regions are interrupted by light fine code patterns or vice versa.

15. A method for measuring angular deviation substantially as herein described with reference to the accompanying drawings.

16. Apparatus for measuring angular deviation substantially as herein described with reference to, and as shown in, the accompanying drawings.

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